

the data representing the forces. The operational criteria may include the timing of variations of polishing pressures, e.g., pressure ramps, as one type of operational criteria that may result in a high processing workload. Other operational criteria relate to the rate at which the position of the polishing pad changes relative to the wafer, and/or to the pad conditioning puck.

Please amend the paragraph starting at page 21, line 11 to read as follows:

Another motion of the polishing head 202 and of the pad 209 on the head 202 for performing polishing of the wafer 206, for example, or for enabling the head 202 and the pad 209 to be conditioned, is movement horizontally (see arrow 209H). It may be understood from the arrows 209H in FIGs. 1A and 1B, for example, that a force may be applied by the polishing pad 209 to certain structure. For example, a force FP-W may be applied by the pad 209 of the polishing head 202 to the wafer 206 (and thus to the wafer carrier 208) at different locations on the wafer 206. Such locations are indicated by the displacement DF-W measured from the axis 212 or 214. These motions may occur at any time "TN" during a CMP cycle. A time TN is referred to below to generally designate any instant of time during a CMP cycle, or during a step in a CMP cycle, whereas a particular time TN is designated by "T" followed by a number, e.g., an initial time T0, or a later time T1. These motions of the pad 209 and the wafer 206 may be referred to as relative movement between the pad 209 and the wafer 206, indicating that in other configurations of the system 200-1, for example, the wafer 206 may be moved (e.g., horizontally) and the pad 209 held against horizontal movement.

Please amend the paragraph starting at page 22, line 1 to read as follows:

The subaperture configuration of the system 200-1 introduces flexibility into the polishing operation by utilizing different or same removal rates on different

regions of the exposed surface 204 of the wafer 206. Unlike the above-described conventional CMP systems wherein an entire polishing pad 209 is in contact with the entire exposed surface of the wafer, in the subaperture CMP system 200-1, at any given time T_N , the size, or value, of an area of a contact surface of the polishing pad 209 (of the preparation head 202) that is in contact with the exposed surface 204 of the wafer 206 may vary. In addition, in the subaperture CMP system 200-1, by preventing movement of the preparation head 202 toward the wafer carrier 208, movement (see up portion of arrow 233, FIG. 2A) of the wafer carrier 208 toward the polishing head 202 results in applying a force $FP-W$ only to selected regions 204R of the exposed surface 204 of the wafer 206, thereby removing excess materials from those selected regions 204R, exclusively, at a particular time T_N . Further, as shown in FIG. 2A, one such selected region 204R of the exposed surface 204 of the wafer 206 is displaced horizontally from, or eccentric relative to, a central axis 212 of the wafer carrier 208. The central axis 212 is concentric with a central axis 214 of the wafer 206 carried by the carrier 208. As shown, the displacement of the force $FP-W$ is indicated by $DF-W$, which is measured horizontally in FIGs. 1A, 1B and 2A. It may be understood from the arrow 209H that the polishing head 202 may move horizontally and contact different ones of the selected regions 204R of the exposed surface 204.

Please amend the paragraph starting at page 28, line 12 to read as follows:

FIG. 4B shows the multiple linear bearing structures 230 (shown in FIG. 2A) as including an array 265 of the linear bearings 253. The array 265 is configured to divide the operation of the multiple linear bearing structures 230 into parts having a short length in the direction of the axes 212 and 214 and small diameters relative to the diameters (e.g., eight inches) of the wafers 206 and the pucks 218. Moreover,

such division locates the linear bearings 253 of the structures 230 at uniformly spaced intervals around a circular path 266 (FIG. 5B-3). In this manner, as the wafer carrier 208 or the pad conditioning head 220 rotate, there is a rapid succession of individual linear bearings 253, for example, located under the eccentric force FP-W that is to be sensed in the operation of the CMP system 200-1.

Please amend the paragraph starting at page 30, line 13 to read as follows:

As described above, FIG. 1B shows the initial orientation of the wafer carrier 208. The carrier 208 includes the retainer ring base 280 and the retainer ring 282. The retainer ring base 280 surrounds and is spaced from the vacuum chuck 262. The retainer ring 282 is designed to be engaged by the polishing pad 209 during the wafer polishing operations, and the polishing pad 209 imparts a force FP-R on the retainer ring 282. The force FP-R is eccentric with respect to the axis 212 of the wafer carrier 208.

Please amend the paragraph starting at page 31, line 5 to read as follows:

Thus the structure 232 is resistant to all except a vertical component (not shown, but identified as FP-RV) of this eccentric force FP-R applied to the retainer ring 282. In detail, the set 270 of three linear bearings 272 assures that structure of the retainer ring 282 is not allowed to move in an undesired manner in response to such an eccentric force FP-R. Thus, the linear bearings 272 assure that such eccentric force FP-R does not move such retainer ring 282, except as follows. The retainer ring 282 is permitted to move vertically, parallel to the initial third orientation of the central axis 212 of the respective wafer carrier 208, which are coaxial. As a result, the eccentric load FP-R (shown in FIG. 2A acting downwardly), minus the force FF relating to the structure 232, is transferred to the retainer ring bearing plate 279 as the

permitted vertical force component FP-RV. Referring to FIG. 2A, for example, it may be understood that the motion of the retainer ring 282 (shown in FIG. 1E-3, for example) that is limited by the structure 232 is independent of the motion of the wafer carrier 208 that is limited by the structure 230.

Please amend the paragraph starting at page 31, line 18 to read as follows:

A force actuator, or linear motor, 290 is mounted between the chuck bearing and load cell plate 260 and the retainer ring bearing plate 279. The linear motor 290 may preferably be provided in the form of a sealed cavity, or more preferably in the form of a pneumatic motor, or an electromagnetic unit, or an electromechanical unit. A most preferred linear motor 290 includes structure shown in FIGs. 7, 12A, 13A, and 14A, including a pneumatic bladder 292 supplied with pneumatic fluid through an inlet (not shown). As shown in FIGs. 5B-1 and 13A the chuck bearing and load cell plate 260 is provided with an annular groove 296 for receiving the bladder 292. The linear motor 290 is selectively actuated by supplying the fluid 293 to the bladder 292 at different amounts of pressure (PB) according to the amount of a desired stroke of the bladder 292. For example, referring to FIGs. 12A and 12B, a maximum stroke of the bladder 292 may be 0.10 inches measured vertically. Such maximum stroke compares to a vertical dimension (or thickness) of the wafer 206, which may be 0.02 inches. For purposes of description, the plate 260 may be said to be fixed in the vertical direction, such that when the fluid 293 is admitted into the bladder 292 the bladder will urge the plate 279 upwardly by a distance corresponding to the particular stroke of the bladder 292 resulting from the pressure of the fluid 293. The bladder 292 will thus move the retainer ring bearing plate 279, and thus move the retainer ring base 280 and the retainer ring 282, up (in this example) relative to the wafer 206

positioned on the vacuum chuck 262, and relative to the pad 209 positioned relative to the retainer ring 282 as shown in FIG. 1C-2, for example.

Please amend the paragraph starting at page 38, line 23 to read as follows:

FIGs. 3A and 9 show the bottom 366 of the upper section 342. Four ports in the upper section 342 are provided for the facilities 338. A first port 368 mates with a similar port (not shown) of the lower section 344 to supply the DI water and vacuum (see arrow 348). The port 368 receives a standard conical seal that extends from the similar port of the lower section 344. The DI water 348 flows, and the vacuum 348 is applied, through the port 368, past an O-ring 370 shown in FIG. 5A-1 to a nozzle 372 shown in FIG. 5B-1 threaded into a threaded port 374 of the plate 260.

Please amend the paragraph starting at page 40, line 13 to read as follows:

A porous layer 297 is mounted on the upper surface 422. The layer 297 is fabricated from porous ceramic material having relatively large pores 297P (FIG. 7). The relatively large pores 297P provide passageways through which the DI water 348 flows or the vacuum 348 is applied from the manifold 420. The large pores 297P are located uniformly across the entire area of the vacuum chuck 262 and thus apply the vacuum from the manifold 420 across the entire area of the chuck 262. Similarly, the large pores 297P supply the DI water 348 all across the area of the chuck 262. Further, the large size pores 297P are not so large that the application of the vacuum 348 will deform the wafer 206 as in the prior use of relatively few (e.g., six) vacuum holes in direct contact with the wafers 206. For all of these purposes, the pores 297P may preferably have a large pore size, and more preferably a pore size in the range of from about twenty to about fifty microns, and most preferably about thirty to about

forty microns, which is significantly greater than typical ceramics having pore sizes in the submicron range to one micron.

Please amend the paragraph starting at page 46, line 3 to read as follows:

The puck is purged to remove polishing debris and other material. The puck 218 is shown in FIGs. 16A, 16B, and 19B as including two disk-like layers 902A and 902B that are adhered to each other. A first layer 902A is fabricated from carbon steel that is provided with perforations 903. The perforations 903 may be apertures having a size of about 0.150 inches, for example. The perforations 903 are uniformly spread over the entire layer 902A. The perforated carbon steel layer 902A is nickel plated. The perforated and nickel plated layer 902A is then coated with diamond material. The layer 902A is in the form of a disk having a diameter of about 9.5 inches, which conforms to the diameter of the outer portion of the retainer ring 282 and to the diameter of the second layer 902B. The second layer 902B is a magnetic disk having an adhesive backing. The layer 902B is provided with smaller perforations or openings 904. For example, the openings 904 may have a size in the range of from about 0.010 inches to about 0.015 inches. The puck 218 is mounted on the pad conditioning head 220 with the layer 902B touching the head 220 so that the diamond coated surface faces the pad 209.

Please amend the paragraph starting at page 48, line 6 to read as follows:

Referring to FIG. 23, the present invention provides a method for controlling relative movement between the wafer 206 and the CMP polishing pad 209. The method may include an operation 1000 of mounting the wafer 206 on the chuck 262. It may be recalled that the wafer 206 has an axis 214, which may

be referred to as an axis of symmetry. This mounted position is described above as the initial position of the wafer axis 214. The method moves to operation 1002 by offsetting the axis 210 of the polishing pad 209 and the axis of symmetry 214 of the mounted wafer 206, which is shown in FIG. 1B. The axis 210 is the axis on which the pad rotates. The method then moves to an operation 1004 by urging the pad 209 and the offset wafer 206 toward each other parallel to the axis of symmetry 214. With the rotary tool changer urging the wafer carrier 208 upwardly and holding the chuck 262 at a fixed position in the direction of the axis 212 of the wafer carrier 208, the urging operation 1004 causes the pad 209 to impose a polishing force, such as the force FP-W, on the contact area APW of the mounted wafer 206 eccentrically with respect to the axis of symmetry 214. In response to the polishing force FP-W, the wafer 206 has the above-described tendency to tilt such that the axis of symmetry 214 tends to move out of parallel with the axis 210, which is the axis of rotation of the pad 209. During the urging, the method moves to an operation 1006 by resisting the tendency of the mounted offset wafer 206 to tilt while allowing the wafer 206 to move parallel to the direction of the axis of rotation 210, and along the initial position of the wafer axis 214. The movement along the initial position of the wafer axis 214 is in response to the force FP-WV in FIG. 2A, for example, and reflects the operation of the linear bearings 232 in response to the eccentric force FP-W. The method may also move to an operation 1008, which during the urging operation and the resisting operation, is performed by measuring the movement of the wafer 206 parallel to the direction of the axis of rotation 210 to indicate a value of the polishing force, i.e., the force FP-W. The operations shown in FIG. 23 are then done.

Please amend the paragraph starting at page 51, line 6 to read as follows:

Referring to FIG. 26, another aspect of the present invention provides a method for controlling relative movement between the wafer 206 and a chemical machining pad 209. The method may include an operation 1040 of mounting the wafer 206 on the chuck 262, the wafer 206 having the axis of symmetry 214 perpendicular to a polishing surface of the pad 209 and coaxial with the carrier axis 212, and parallel to the axis of rotation 211 of the pad 209. The method moves to operation 1042 by offsetting the axis of rotation 211 of the pad 209 from the axis of symmetry 214 of the mounted wafer 206. The method moves to operation 1044 by resisting movement of the polishing surface of the pad 209 toward the wafer 206. The chuck support plate 260 is provided for this purpose. The chuck 262 is movable relative to the chuck support plate 260. The method moves to operation 1046 by providing the retainer ring unit (e.g., ring 282 and base 280) around the chuck 262 for movement to retain the wafer 206 on the chuck 262 (e.g., assist in placing the wafer 206 on the chuck 262, FIG. 12B). The retainer ring 282 may also expose the wafer 206 to the surface of the pad 209 for polishing (FIG. 14A). The method moves to operation 1048 by providing the chuck 262, the chuck support plate 260, and the retainer ring units (280 and 282) with a plurality of pairs of linear bearing assemblies 230 and 232, each of the assemblies having a housing 254 or 274 provided with a bearing axis perpendicular to the polishing surface of the pad 209. Each of the assemblies has the linear shaft 258 or 278 received in a respective one of the housings 254 or 274. The first set 252 of the assemblies is between the chuck 262 and the retainer ring units (280 and 282), and the second set 270 of the assemblies is between the chuck 262 and the chuck support plate 260. The method moves to operation 1050 by holding the chuck support plate 260 at a fixed position along the axis 212 to resist the movement of the polishing surface of the pad 209 toward the wafer 206.

Alternatively, the plate 260 may be urged toward the pad 209. On either case, the pad 209 imposes the polishing force FP-W on the mounted wafer 206 and the force FP-R on the retainer ring 282, each force being eccentric with respect to the axis of symmetry 214. In response to the polishing force FP-W the wafer 206 and the chuck 262 have the tendency to tilt such that the axis of symmetry 214 tends to move out of parallel with the axis of rotation 210. Referring to FIG. 27, during the holding operation 1050 an operation 1052 is performed by which the first set 252 of the assemblies is effective to limit the movement of the retainer ring 282 to movement parallel to the axis of symmetry 214. During the holding of the chuck support plate 260, for example, operation 1054 is performed by which the second set 270 of the assemblies is effective to limit movement of the chuck 262 relative to the chuck support plate 260 to movement parallel to the axis of symmetry 214.

Please amend the paragraph starting at page 54, line 8 to read as follows:

Referring to FIG. 31, the present invention also provides a method for controlling relative movement between the chemical machining pad 209 and the pad conditioning puck 218. The method may include an operation 1090 of mounting the puck 218 on the chuck 322, the puck 218 having the initial axis of symmetry 224 and a puck surface parallel to the polishing surface of the pad 209. The pad 209 has the axis of rotation 211. The method moves to operation 1092 by offsetting the axis of rotation 211 of the pad 209 from the axis of symmetry 224 of the mounted puck 218. The method moves to operation 1094 by providing the chuck support plate 308 for resisting movement of the polishing surface of the pad 209 toward the puck 218, the chuck 322 being movable relative to the chuck support plate 308. The method moves to operation 1096 by providing the chuck 322 and the chuck support plate 308 with a plurality of pairs of linear bearing assemblies 304. Each of the assemblies 304 has a

housing 316 provided with a bearing axis perpendicular to the polishing surface of the pad 209. Each of the assemblies 304 has a linear shaft 320 received in a respective one of the housings 316. The assemblies 304 are between the chuck 322 and the chuck support plate 308. The method moves to operation 1098 by holding the chuck support plate 308 at a fixed position to resist the movement of the polishing surface of the pad 209 toward the puck 218. The pad 209 imposes the conditioning force FP-W on the area APC of the mounted puck 218 eccentrically with respect to the axis of symmetry 224. In response to the conditioning force FP-C, the chuck 322 and the puck 209 on the chuck 322 have a tendency to tilt such that the axis of symmetry 224 tends to move out of parallel with the axis of rotation 211. During the holding of the chuck support plate 308 at the fixed position the method moves to an operation 1098 in which the assemblies 304 are effective to cause the mounted puck 218 to resist movement of the polishing surface of the pad 209 and the puck 218 towards each other. Referring to FIG. 32, the method moves to an operation 2000 to limit movement of the chuck 322 relative to the chuck support plate 308 to movement parallel to the initial position of the axis of symmetry 224. In this manner the puck surface remains parallel to the polishing surface. The method may move to operation 2002 by sensing the limited movement of the chuck 322 relative to the chuck support plate 308 to indicate an accurate value of the conditioning force FP-CV.

Please amend the paragraph starting at page 57, line 8 to read as follows:

Referring to FIG. 36, another aspect of the method of the present invention relates to a method of conditioning a polishing pad. The method starts with an operation 2070 of mounting the puck 218 on the chuck 322 with the puck axis 224 of symmetry perpendicular to polishing surface of the pad 218 and the puck conditioning

surface parallel to the polishing surface. The method moves to an operation 2072 of offsetting the axis of rotation 210 from the axis of symmetry 224 of the mounted puck 218 with the axes 210 and 224 parallel to define an initial orientation of the puck 218. The method moves to an operation 2074 of moving the polishing surface of the pad 218 and the conditioning surface of the puck 218 toward each other. The method moves to an operation 2076 of providing the array 265 of linear bearing assemblies 310 adjacent to mounted puck 218. Referring to FIG. 37, the method moves to an operation 2078 of using the assemblies 310 during the move operation 2074 to substantially limit movement from the initial orientation and permit only movement of the mounted puck 218 with the conditioning surface parallel to the polishing surface. The method moves to an operation 2080 of sensing the limited movement to indicate an accurate value of the polishing force FP-C applied on the conditioning surface.

Please amend the paragraph starting at page 64, line 1 to read as follows:

Concerning criteria 1 of configuration criteria 2122, an end detection situation related to decreasing polishing pressure is described with reference to FIG. 42A, which shows the wafer 206 overlapped by the polishing pad 209. The polishing pressure may be decreased with time in order to decrease the polishing rate of the wafer 206 as the desired wafer thickness is approached. Time TN may be an initial time T0 as shown in FIG. 1C-1 with the edge of the pad 209 tangent to the Y axis center line of the wafer 206. The time T0 identifies the point at which the edge of the pad 209 engages the contact area APW of the wafer 206, with the edge adjacent to the center line of the wafer (see h1). The corresponding contact area APW of the pad 209 is shown tending to remove the wafer 206 at a higher rate from parts of the wafer 206 that are nearest to the center line of the wafer (at h1) as compared to lower removal

rates nearer to or at the edge 2126 of the wafer 206 corresponding to time Td, for example. The variation in removal rates is shown by a series of dashed lines 2128. It may be understood that in a period of time from time T0 to time Tc the pad 209 has removed a thickness of TH1 from the wafer 206 adjacent to the center line h1, whereas in the same time period the pad 209 has removed a thickness substantially less than TH1 from the wafer 206 adjacent to the edge 2126 of the wafer 206.

Please amend the paragraph starting at page 67, line 3 to read as follows:

Assuming the system 2100 has been selected according to these configuration criteria 2122, system 2100 may be used as follows. The recipe editor 2116 has defined all criteria related to the CMP process in the form of the edited recipe 2114. The edited recipe 2114 is output to a bus 2144 and stored in a hard drive 2146, for example. The edited recipe 2114 may include data corresponding to the list of process variables set forth in Appendix A below. The processor 2110 reads the edited recipe 2114 from the hard drive 2146 and processes data necessary to set up and operate the above-described hardware of the CMP system 200-1. This includes axis motion data, including pad motion data 2150, pressure profile data 2152 (for each area AP), process sequence data, and other data necessary to operate the carrier 208, the polishing head 202 and the retainer ring motor 290, for example. The processor 2110 defines the edited recipe 2114 in terms of a table of sequences in which steps are taken to perform the CMP operations.

Please amend the page 83, Appendix B, paragraph numbered 11, to read as follows:

11. EC2 – returns or sets right limit for the encoder.